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Supporting Information

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A Low Cost Aqueous Zn-S Battery Realizing Ultrahigh Energy Density

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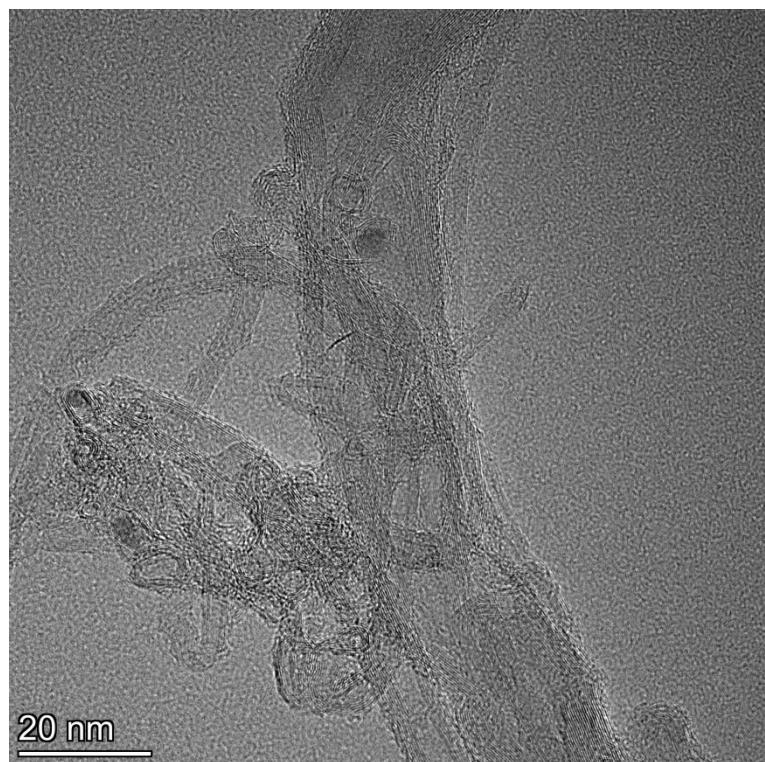


Figure S1. TEM image of S@CNTs-50.



Figure S2. Optical photograph of 1M $\text{Zn}(\text{CH}_3\text{COO})_2$ without (left) and with 0.05 wt% I_2 (right).

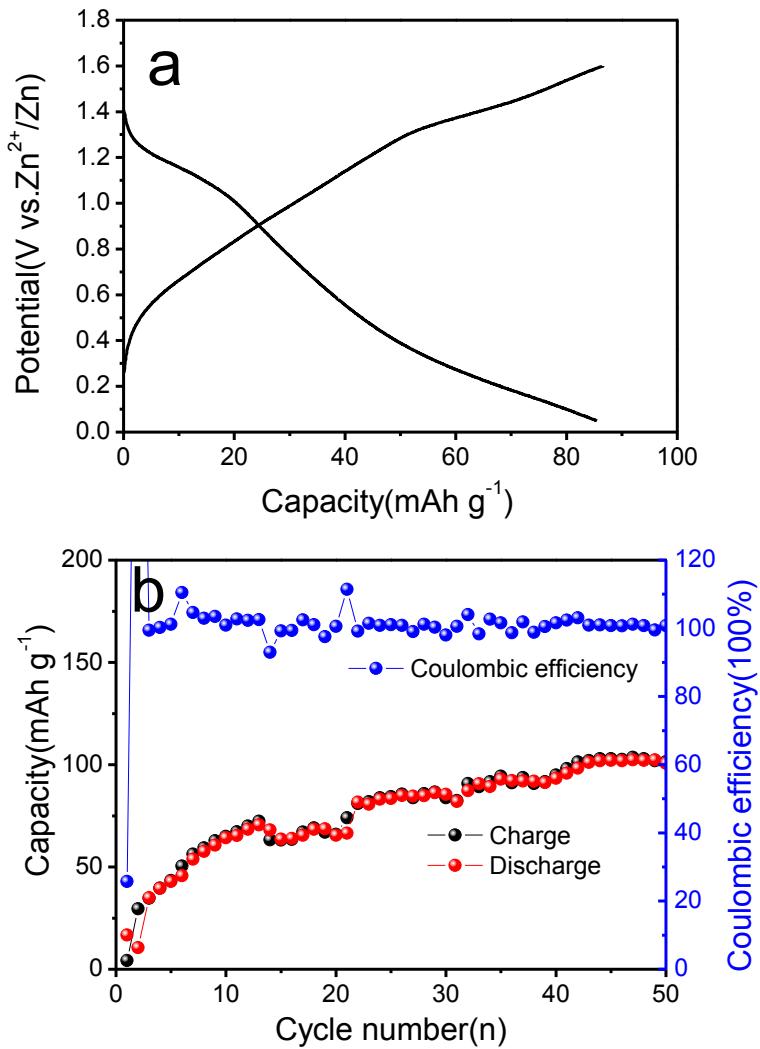


Figure S3. (a) Charge and discharge curves and (b) cycling performance of CNTs electrode in the electrolyte of $1 \text{ M Zn}(\text{CH}_3\text{COO})_2 + 0.05\text{wt\% I}_2$ at a current density of 100 mA g^{-1} .

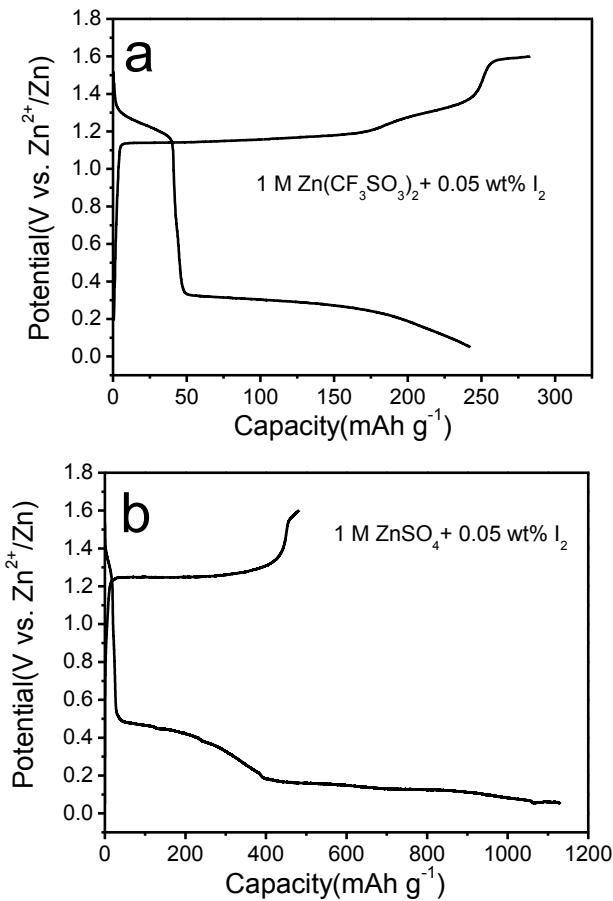


Figure S4. Charge and discharge curves of (a) 1 M $\text{Zn}(\text{CF}_3\text{SO}_3)_2$ and (b) 1M ZnSO_4 with I_2 additive.

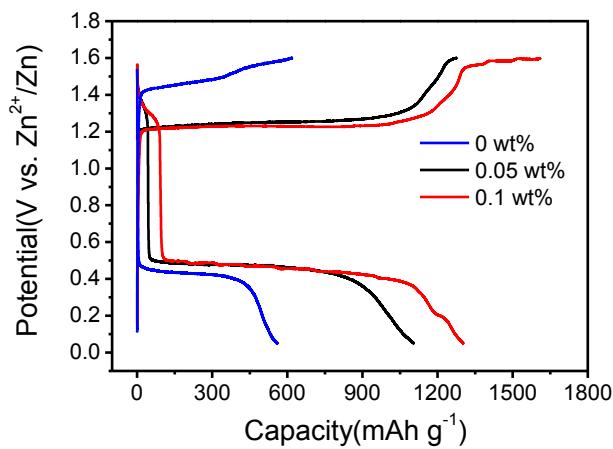


Figure S5. Charge and discharge curves of S@CNTs with different contents additive.

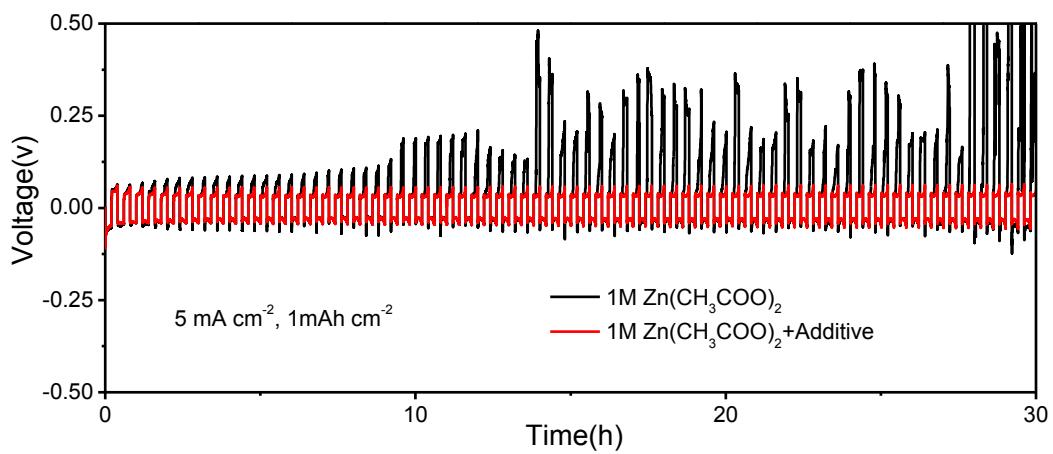


Figure S6. Cycling performance of Zn symmetrical cells in the electrolyte of 1 M Zn(CH₃COO)₂ with or without I₂ additive.

Table S1. Cost of electrode materials

Compart	Price (US\$/kg)	Ref.
Zn	2	S1
S	0.25	S2
CNTs	20	S3

To simplified the calculation, the cost of 1 M $\text{Zn}(\text{CH}_3\text{COO})_2$ electrolyte and additive are ignored because of the very lower cost than other counterpart. Since the energy density of S@CNTs is 502 Wh kg⁻¹ and the total cost of Zn, S and CNTs are 22.25 \$/kg, the cost of can be calculated to be $1000 \times (2 + 0.25 + 20) / 502 = \text{USD } \$ 45/\text{kWh}$.

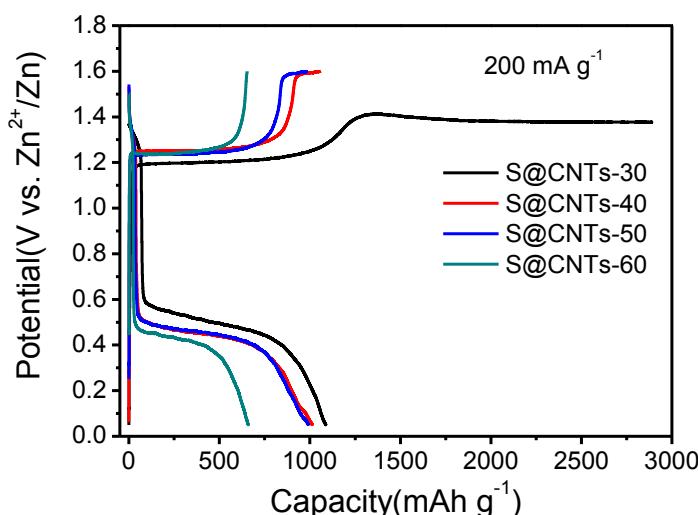


Figure S7. Charge and discharge curves of four electrodes of S@CNTs with different sulfur contents at 200 mA g⁻¹ in the electrolyte of 1 M $\text{Zn}(\text{CH}_3\text{COO})_2$ with I_2 additive.

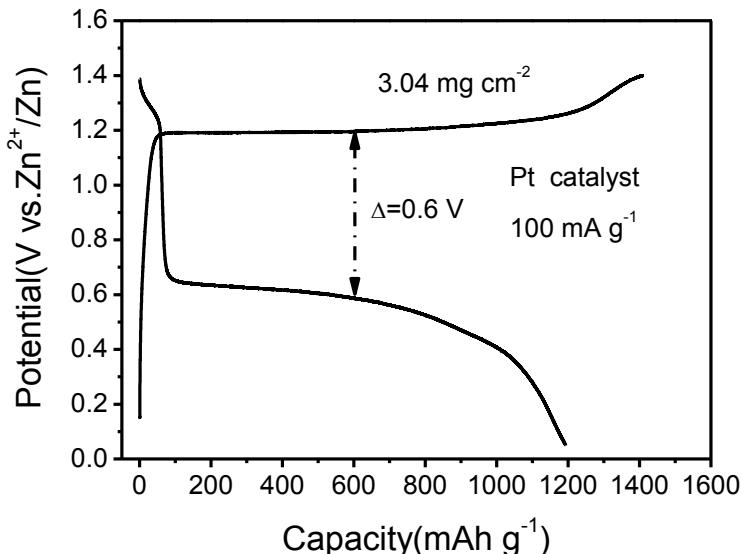


Figure S8. Charge and discharge curve of S@CNTs with 5wt% Pt at 100 mA g⁻¹ with a sulfur loading of 3.04 mg cm⁻².

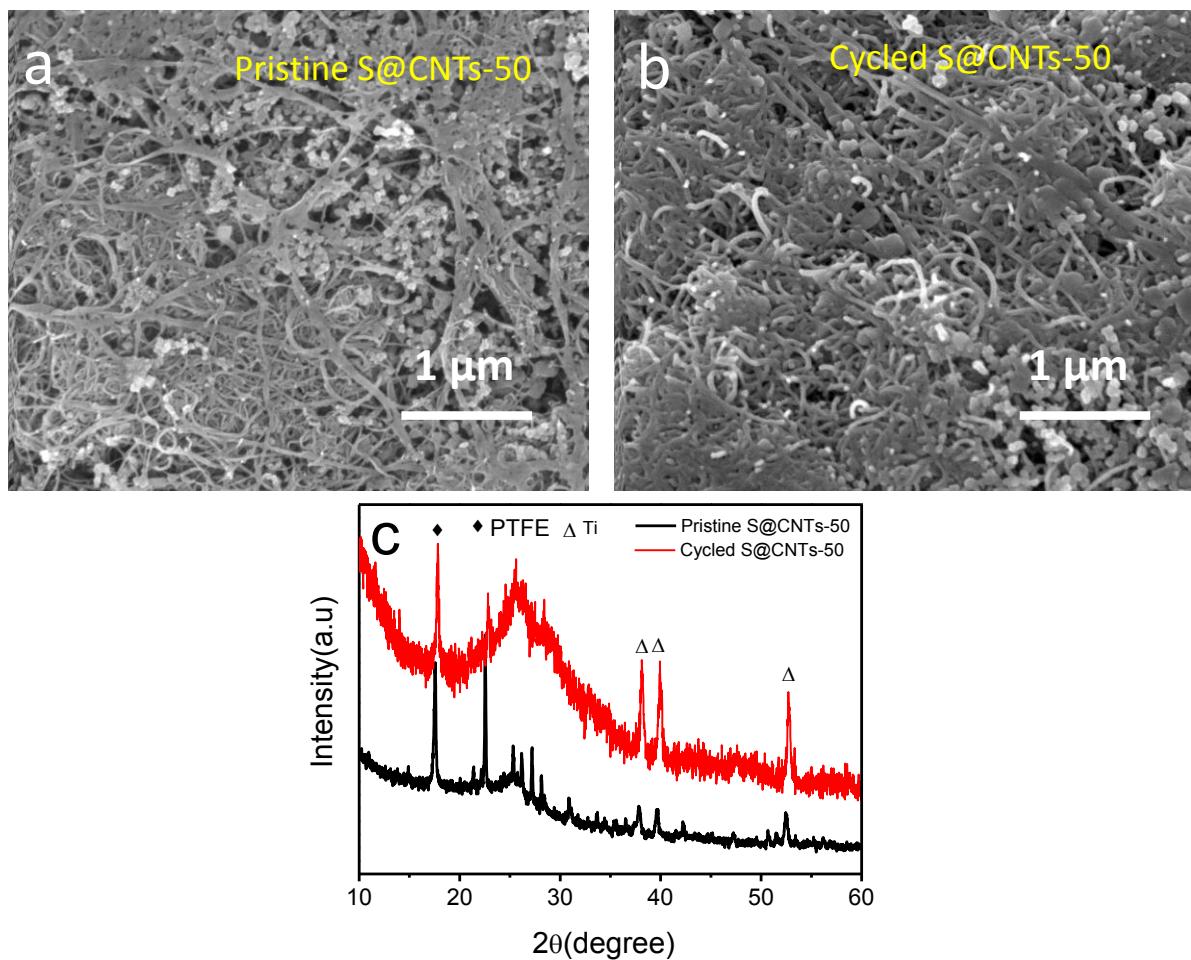


Figure S9. SEM images of S@CNTs-50 (a) before and (b) after 160 cycles, (c) XRD patterns of pristine and cycled S@CNTs-50 electrodes.

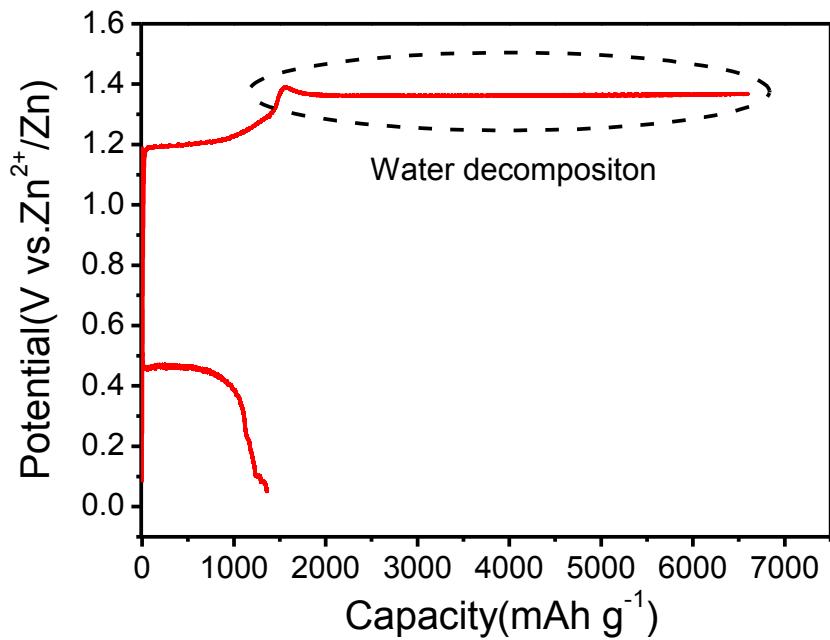


Figure S10. Charge and discharge curves of S@CNTs-50 at a current density of 20 mA g^{-1} .

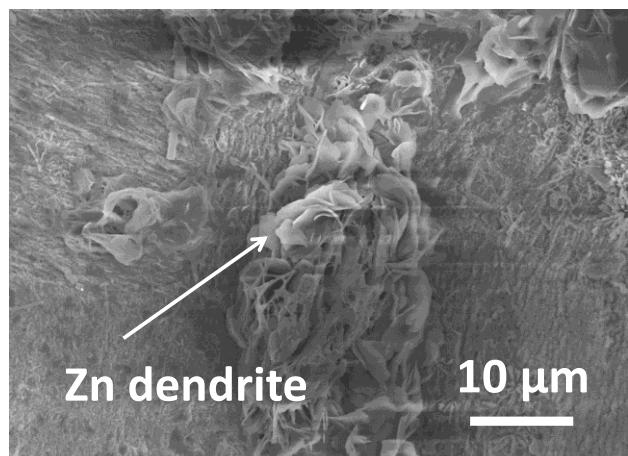


Figure S11. SEM image of cycled Zn.

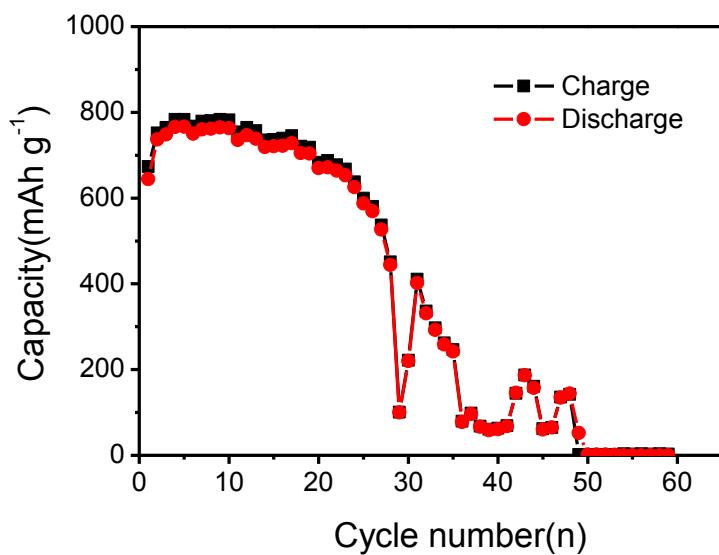


Figure S12. Cycling of S@CNTs-50 at a current density of 1000 mA g⁻¹.

Table S2. Comparison of S@CNTs-50 with other reported cathode for aqueous Zn-based batteries.

Materials	Voltage (V)	Capacity (mAh g ⁻¹)	Energy density (Wh kg ⁻¹)	Current density (A g ⁻¹)	Cycling	Capacity retention	Ref.
Zn _{0.25} V ₂ O ₅ ·nH ₂ O	0.7	282	250	2.4	1000	82	<i>Nat. Energy</i> 2016, 1, 16119
Na ₃ V ₂ (PO ₄) ₂ F ₃	1.62	65	100	1	4000	95%	<i>Energy Storage Mater.</i> 2018, 15, 14
ZnMn ₂ O ₄	1.4	150	202	0.5	500	94%	<i>J. Am. Chem. Soc.</i> 2016, 138, 12894
ZnHCF	1.7	65	100	0.06	100	76	<i>Adv. Energy Mater.</i> 2015, 5, 1400930
Na ₃ V ₂ (PO ₄) ₃	1.1	97	100	0.05	100	74%	<i>Nano Energy</i> 2016, 25, 211
VS ₂	0.6	190	123	0.5	200	82%	<i>Adv. Energy Mater.</i> 2017, 7, 1601920
Zn ₃ V ₂ O ₇ (OH) ₂ ·2H ₂ O	0.7	200	150	0.2	300	68%	<i>Adv. Mater.</i> 2017, 1705580
K ₂ V ₆ O ₁₆ ·2.7H ₂ O	0.8	230	172	6	500	82	<i>J. Mater. Chem. A</i> , 2018, 6, 15530
Na ₂ V ₆ O ₁₆ ·3H ₂ O	0.8	361	287	14.4	1000	80	<i>Nano Lett.</i> 2018, 18, 2402
Zn ₂ (OH)VO ₄	0.8	140	200	4	2000	89%	<i>Adv. Mater.</i> 2018, 1803181
V ₂ O ₅ ·nH ₂ O	0.7	372	290	6	900	71%	<i>Adv. Mater.</i> 2017, 1703725
Zn ₂ V ₂ O ₇	0.8	200	166	4	1000	85%	<i>J. Mater. Chem. A</i> 2018, 6, 3850
PTO	0.8	336	186.7	3	1000	70	<i>Angew. Chem. Int. Ed.</i> 2018, 57, 11737
VO ₂	0.6	280	160	4	1000	99%	<i>Energy Storage Mater.</i> 2019, 17, 143
Na ₃ V ₂ (PO ₄) ₃	1.23	114	140	0.5	200	75	<i>Nano Energy</i> 2019, 58, 492
I ₂ @C-50	1.2	210	237	0.1	50	87%	<i>J. Mater. Chem. A</i> 2020, 8, 3785
S@CNTs-50	0.5	1105	502	2	300	76%	This work

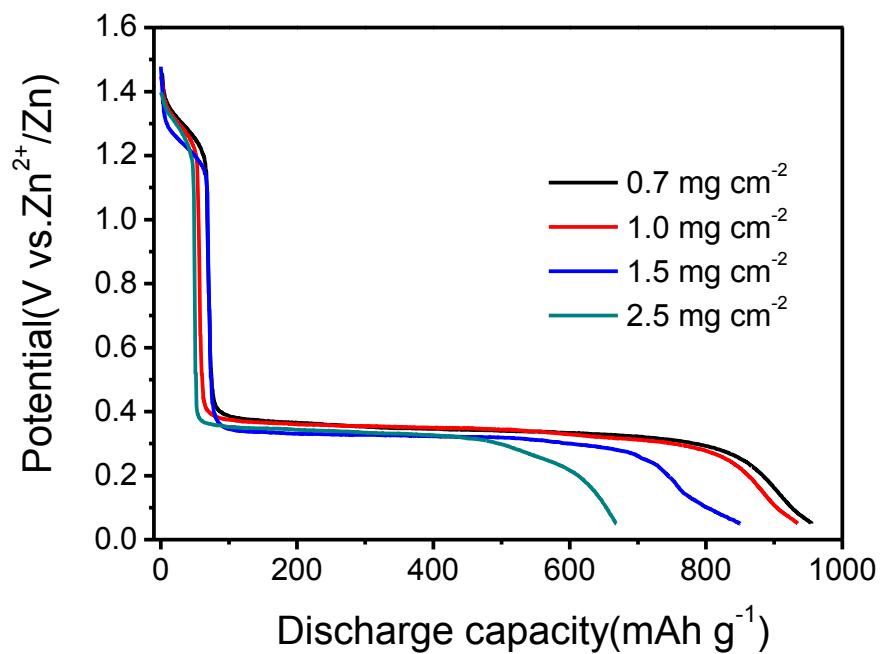


Figure S13. Discharge curves of S@CNTs-50 with different sulfur loadings at a current density of 1000 mA g⁻¹.

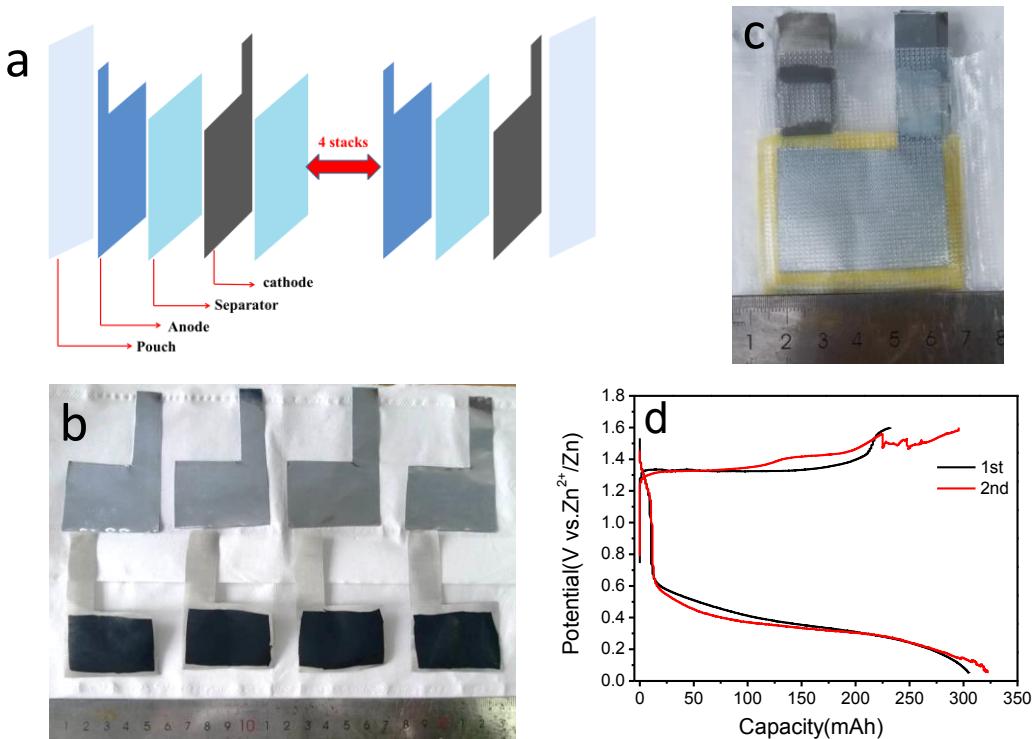


Figure S14. (a) Structural illustration, (b) optical photograph of anodes and cathodes, (c) packing battery with four anode-separator-cathode stacks with a designed capacity of 0.35 Ah, (d) charge and discharge curves of packing battery at a current density of 100 mA g⁻¹.

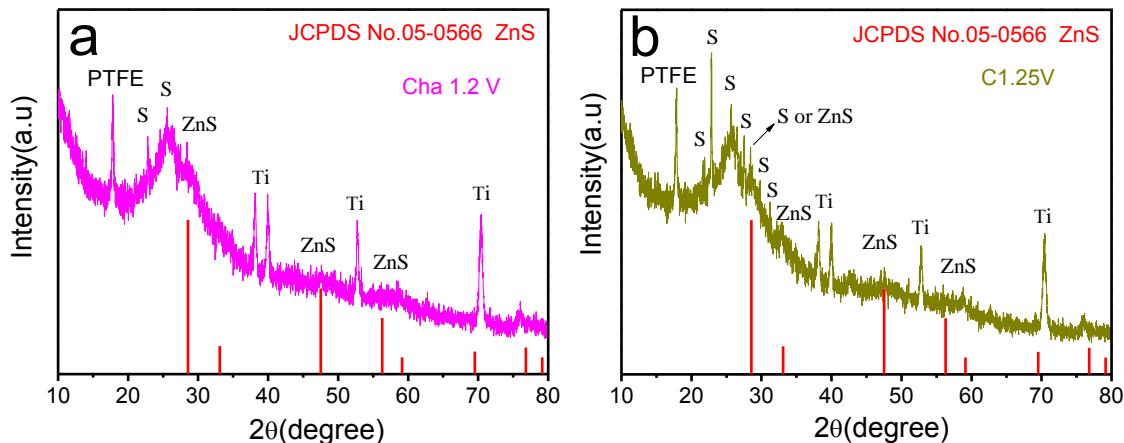


Figure S15. XRD patterns of S@CNTs-50 at charged (a) 1.2 V and (b) 1.25 V.

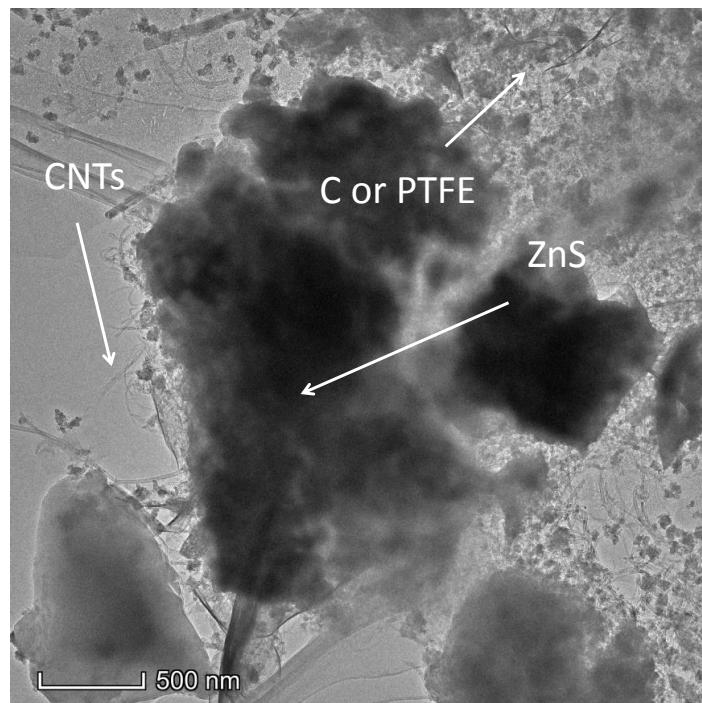


Figure S16. TEM image of S@CNTs-50 at fully discharged state.

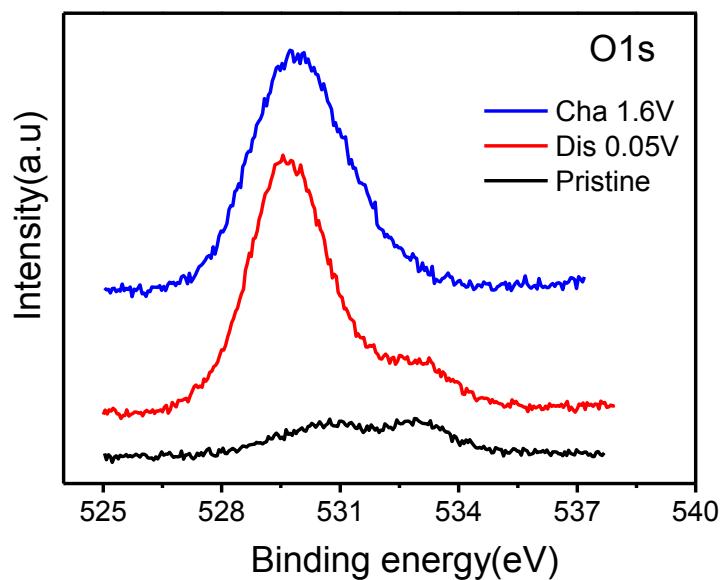


Figure S17. XPS of O1s at the pristine, fully discharged state of 0.05V and fully charged state of 1.6 V state.

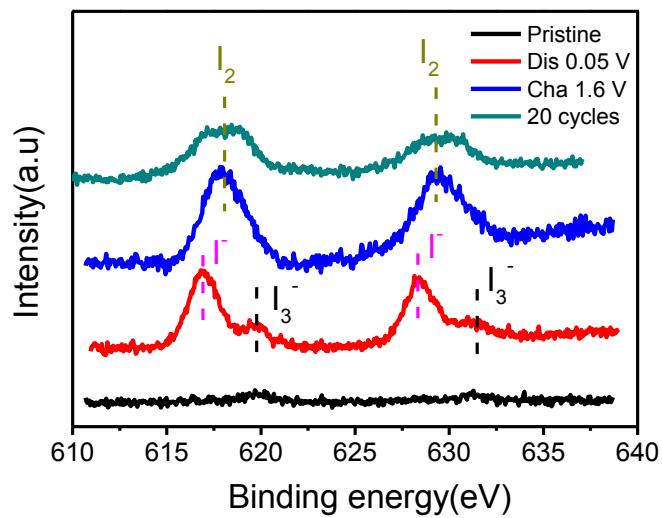


Figure S18. XPS of I3d of S@CNTs-50 at the pristine, fully discharged state of 0.05V, fully charged state of 1.6 V state, and after 20 cycles.